Kendall and Welch

Design of a Power Plant For a Paper Mill

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DESIGN OF A POWER PLANT FOR A PAPER MILL

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

MYRON AVERY KENDALL and FRANK MARSHALL WELCH

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IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

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CONTENTS

Page

THE PAPER MILL 1

HISTORY OF PAPER MANUFACTURE 1

PROCESS OF FELT MANUFACTURE 2

STANDPOINT OF DISCUSSION 2

BUILDINGS REQUIRED 3

MACHINERY REQUIRED 4

THE POWER PLANT 6

COMPLETION OF BUILDING PLANS 6

Summary of Required Power 6

Boiler Room Capacity 8

Plans of Mill 9

ENGINE ROOM 9

Existing Conditions 9

Beater Room Power Requirements 10

Corliss Engine 11

Mechanical or Electrical Power 12

Generators 13

Comparative Merits of the Corliss Engine and Steam Turbine 14

Turbo-Generators 18

Alternating or Direct Current,- Speed Control . . . 19

Source of Water Supply 21

Engine Room Auxiliaries 24

CONTENTS

Page

BOILER ROOM 26

Handling of Fuel 26

Feed Water 30

Draft 32

Piping 32

C O N C L U S I O N 38

DESIGN OF A POWER PLANT FOR A PAPER MILL

T H E   P A P E R   M I L L

HISTORY OF PAPER MANUFACTURE

As early as 105 A. D. the Chinese are said to have made paper of vegetable fiber, hemp, rags, and old fishing nets. For hundreds of years previous to this, Egyptians wrote on thin slices of cellular tissues laid across others, the whole moistened with Nile water and pressed and smoothed down with ivory or shell. This was called Egyptian papyrus, from which is derived our present word paper. It was, however, not until the fourteenth century that paper came into universal use.

Many different kinds of paper are made, and although the processes are similar, the fibrous constituents vary greatly. Print papers usually consist of two wood fibers, one made mechanically and the other chemically. The latter process consists of cooking either spruce or poplar with sulphide of lime or caustic soda. Writing-paper is made entirely of rags which are cooked and given a milk of lime treatment. Cardboards and manilla contain mostly straw and reworked paper. Roofing-felts are composed of linen and cotton rags and straw, and it is a plant designed for the ex-

clusive output of this product that is to be discussed and analyzed in this paper.

PROCESS OF FELT MANUFACTURE

The plant will have a capacity of 70 tons of dry felt per day. The saturation process will not be considered in this mill. The proportions of rags and straw vary according to the thickness of the paper, which varies from #12 to #70. #12 is the heaviest roofing felt in use, and this mill will be designed to make this kind of paper. For such paper 90% of rags and 10% of straw are beaten together in large beating engines. The straw is previously prepared by cooking under 40 pounds steam pressure for from 8 to 10 hours in closed rotaries, with a milk of lime solution. After passing through refining processes, the pulp is screened and rolled and pressed between large cylindrical driers.

STANDPOINT OF DISCUSSION

The aim of this paper is to specify and locate the most economical number and kinds of power developing units to drive a given amount of machinery. The power required for the given machinery must not only be assumed, but the relative locations of the various machines and of the power plant must be previously settled upon. Therefore the following pages will first enumerate the buildings and

machinery required and the amount and kind of power needed to drive each machine. From these figures a sufficient estimate of the required mechanical and electrical power and boiler capacity will be made so that the sizes and locations of the engines, generators, boilers, and auxiliaries can be approximated and a definite size and arrangement of engine and boiler room decided upon.

The discussion will include descriptions and drawings showing the most practical and economical arrangement of the power plant, and will give reasons why each unit was decided upon. The reasoning will be composed of arguments in favor and against each style of unit considered, and will tell why the various styles of machines which are operating under different conditions, such as constant and variable speeds, etc., require certain kinds of driving forces.

The process of paper manufacture in order to operate economically must run without delays or shut-downs. Therefore 24 hours will be considered to constitute a day at this mill, and all machinery and generating units will be designed to produce 70 tons of dry roofing felt per day.

BUILDINGS REQUIRED

After thorough investigation as to the available railroads and shipping accommodations and the most accessible arrangement of side-tracks and loading platforms, the store-

houses for the straw, rags, and finished products are located. Between the buildings the entire plant is arranged according to the order of processes and the most economical handling of the materials.

The rag storage building will be one of the largest, owing to the fact that sufficient quantities of rags for such a mill can not be obtained in this country, and large quantities must be imported. The rag cutting room, straw cooking and storage house, pulp beating room and paper machine room adjoin each other in the order named. Parallel to these buildings must be located the boiler room, engine room and a machine repair shop. The required size, arrangement and location of each room of the plant are best shown in the plan, Plate 1.

MACHINERY REQUIRED

A plant of 70 tons daily capacity not only requires machines of the largest type, but requires several machines of the same kind for each process. For cooking the straw 4 rotary cookers 16 feet in diameter must be used; 8 large rag cutters are required; and in the beating room, which must be the largest room of the plant, 36 beating engines must be used. Beneath the beater room 4 large stuff-chests are required, each having mixing machinery and a circulating pump. 2 refining engines complete the process of

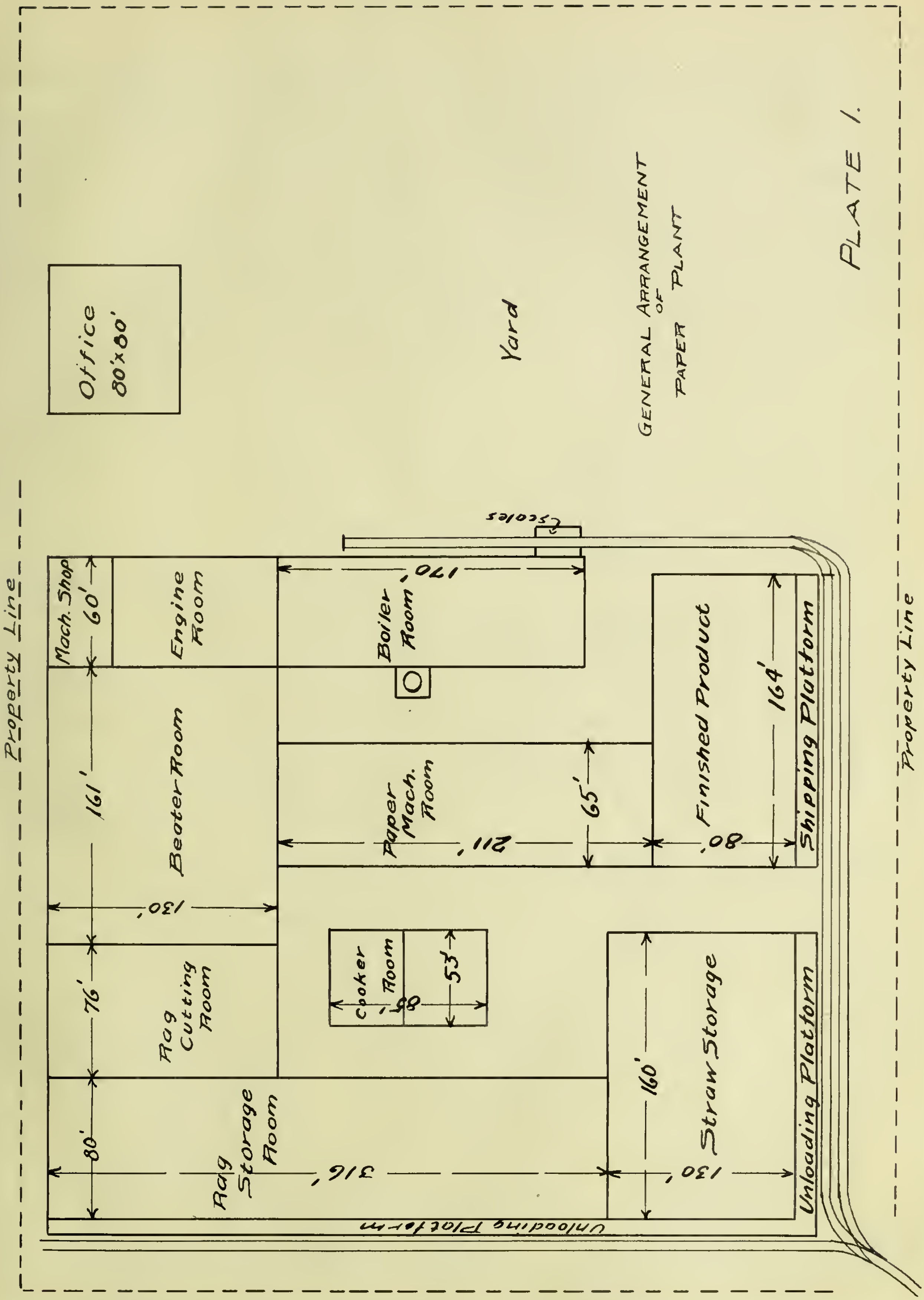

Property Line
Office 80'x80'
Yard
General Arrangement of Paper Plant
Plate I.
Scales
Mach. Shop
60'
Engine Room
Boiler Room
170'
Beater Room
161'
130'
Paper Mach. Room
211'
65'
Finished Product
80'
164'
Shipping Platform
Property Line
Rag Cutting Room
76'
Cooker Room
58'
53'
Rag Storage Room
80'
316'
Straw Storage
160'
130'
Unloading Platform
Unloading Platform

PLATE I.

this room. In the machine room 2 more stuff-chests with their mixers and pumps and 2 paper machines of the three-width size are required, each of which makes rolls of paper 114 inches wide. In connection with these large processes a great deal of auxiliary machinery is required, such as elevators, conveyers, calenders, pumps, and the machinery in the repair shop.

T H E P O W E R P L A N T

COMPLETION OF BUILDING PLANS

Summary of Required Power

Before continuing further a rough estimate must be made of the power required, in order that the size and arrangement of the engine and boiler room may be sufficiently decided upon, and so that the plans and elevations of the entire plant may be completed.

The following is a list of machines and the power required to drive each:

NUMBER OF MACHINES	MACHINES IN THE ORDER OF THE PROCESSES	H. P. TO DRIVE EACH	TOTAL H. P.
2	Elevators in Rag Storage Room	7.5	15
2	Rag Fans	20.	40
8	Rag Cutters	8.	64
4	Rotary Cookers (2 operated at one time)	7.5	15
2	Rag Conveyers to Beater Room	20.	40
3	Straw Conveyers to Beater Room	10.	30
36	Beating Engines	50.	1800
4	Beater Stuff-Chests (mixers)	5.	20
4	Beater Stuff Pumps	7.5	30
2	Jordan Refiners	80.	160
2	Machine Stuff-Chests (mixers)	5.	10
2	Machine Stuff Pumps	7.5	15
2	Paper Machines	175.	350
1	Pressure Pump for Machine Showers	40.	40
1	Mill Supply Pump	70.	70

Total 2699

Machine Repair Shop 10

Lighting (approximate) 150

Engine and Boiler Room Auxiliaries 400

Total Estimate 3259

Boiler Room Capacity

It is evident that a power plant generating about 3500 engine H. P. would be sufficient to operate this mill twenty-four hours each day, and would be large enough to allow for repairs or breakdowns in one part and still run efficiently. If the evaporation of 14.5 pounds of water is taken to represent one I. H. P., and 30 pounds of water at 70 pounds pressure from and at 100^{o} F. represent one boiler H. P., a boiler plant of about 1700 H. P. will be required.

The steam drying cylinders on the paper machines require the evaporation of 2 pounds of water for every pound of paper that is made; therefore

$$\frac{2 \times 70 \times 2000}{30 \times 24} = 390 \text{ boiler H. P.}$$

will be needed to make 70 tons of paper every twenty-four hours. 40 boiler H. P. is also required to furnish steam for the rotary cookers. The plant will be heated by a direct piping system, using steam at about 10 pounds pressure. A separate return pipe will be used, which will return all the water to the feed-water heater. The floor area of this mill will not exceed 200,000 square feet, and to sustain a constant temperature of 55^{o} F. in such a plant when the outside atmosphere is -10^{o}, about 160 boiler H. P. must be provided. These live steam requirements increase the needed boiler room capacity to 2290 H. P.

On account of high efficiencies, large grate areas

and heating surfaces, Babcock and Wilcox double deck boilers will be used. 6 boilers of 400 H. P. capacity each, will be installed, and as there is a possibility of at sometime adding a saturation plant to the proposed mill, space will be left in the boiler room for 3 more boilers. By figuring in conjunction with working blue-prints which have been furnished by the Babcock and Wilcox people, and by allowing for suitable coal-bins and bunkers and fuel handling machinery, it is found that a boiler room 60' x 140' will be sufficient.

Plans of Mill

Now that the size and location of every room and building of this mill except the engine room have been decided upon, by consulting the unfinished plans and by comparison with similar power stations, it is found that more than sufficient room is left in the space adjoining the beater and boiler rooms to accommodate a large engine room. Therefore the building plans will now be completed, and after sufficient space has been allotted in the engine room for the required generating units and their auxiliaries, the remaining rectangular space will be occupied by a machine repair shop.

ENGINE ROOM

Existing Conditions

The building plans now being complete, a definite idea of the area to be lighted and heated is found. Every de-

tail is known of the power requirements, and the boiler room location and capacity have been settled upon. It now remains to decide upon and to determine the most desirable, economical and easily maintainable units or combination of units to drive the proposed mill. The existing conditions pertaining to each machine or group of machines will be considered, and the relative advantages and disadvantages of various reciprocating engines, steam turbines, and electric generators will be discussed.

Beater Room Power Requirements

The machinery in the beater room, which is the largest and requires as much power as all the rest of the plant, is mostly composed of beating engines. Electrical power can not conveniently be installed for these machines, because the rolls must be constantly raised and lowered according to the changeable consistency of the pulp, and if motors were used, they must be either direct connected or geared to the roller shafts. Electric motors driving the rolls by means of Morse and Reynolds silent gear chains have been used for this purpose, but have not proved satisfactory under the existing conditions. Therefore either belt or rope drive must be used in the beater room, and owing to less friction and easier maintenance, the beater room machinery will be rope driven.

Corliss Engine

For a mechanical drive of the required capacity the Corliss compound engine running condensing at once presents itself as the most suitable and economical unit for driving the beater room machinery. The fact that a great variation in speed, owing to the different qualities of pulp, must exist in the beater room, and that other conditions make the beater room independent and separate from the other parts of the mill, makes it advisable to operate this process with units independent of those used to drive the rest of the plant.

It then only remains to decide whether duplicate units should be installed in order to be able to operate the beater room by overloading one engine in the event of the other breaking down, or whether one large and more economical unit would be sufficient. All the pulp that is made in the beater room passes through the large stuff-chests or mixing boxes. These reservoirs are large enough to store a sufficient amount of pulp to furnish the following processes for three hours in case of any accident in the beater room. With such a time allowance for repairs, and the fact that the plant will not run from five o'clock Saturday nights until seven o'clock Monday mornings, it is found that one engine will be the most suitable for this purpose.

From the machinery list the following are located

on or below the beater room floor and will be driven by the proposed Corliss engine:

36 Beating Engines	1800 H. P.
4 Stuff-Chests	20 H. P.
4 Stuff Pumps	30 H. P.
8 Rag Cutters	64 H. P.
2 Jordan Refiners	160 H. P.
Total	2074 H. P.
15% Transmission Losses	311 H. P.
Total Required . .	2384 H. P.

Two main line shafts beneath the floor of the beater room will distribute power to the various machines, and an engine carrying two large rope sheaves on its crank-shaft will be installed. The engine will be located between the two main shafts so that each large sheave will drive one main shaft. A 2400 H. P. Corliss cross compound, horizontal, condensing engine made by the Allis-Chalmers Company of Milwaukee, will be installed.

Mechanical or Electrical Power

It must now be decided whether or not the remainder of the plant will be driven by mechanical or by electrical power. The facts that the beater room is to be driven by a Corliss engine, and that the paper machines proper require variable speed drives, point vary favorably to the installa-

tion of a duplicate of the other Corliss engine. However, the remaining machinery in the plant is more or less scattered, which would result in great complications of shafting and a great loss of power in transmission if mechanical drive were adopted. With these reasons in mind, coupled with the fact that at least one generator must be installed for lighting purposes, the motor drives will be adopted for the rest of the mill. For this purpose one or two large generators must be installed.

Generators

The power which must be furnished by the electrical units is as follows:

2 Elevators	15	H. P.
2 Rag Fans	40	"
2 Rotary Cookers	15	"
2 Rag Conveyers	40	"
3 Straw Conveyers	30	"
2 Stuff-Chests	10	"
2 Stuff Pumps	15	"
2 Paper Machines	350	"
Machine Repair Shop	10	"
Lighting 165,000 Square Feet	100	"
Boiler Room Auxiliaries	75	"
Total	700	"
10% Transmission Losses	70	"
Total Required	770	"

It is evident that the electrical units must be able to furnish constantly 770 H. P. or 575 Kw. In several of the processes which are dependent upon the electrical units for power it is very essential that no unlooked for delays or stoppages shall occur. For this reason there must be two units installed so that one can operate the plant alone in case the other should become disabled. Therefore units must be chosen for this purpose which can operate efficiently under 20% to 30% overload.

The question which now arises is what kind of engines will best drive the generators. The boiler room has been sufficiently specified, so that any form of internal combustion engines are practically eliminated. In fact there seems to be just two units, either of which has proved itself satisfactory and absolutely reliable for the same purposes and under the same conditions that are to be confronted in this plant. These are the steam turbine and the Corliss engine, either of which would contain direct connected generators. Again the duplication of the other Corliss engine at first looks advisable, but as one of these engines would be connected to generators and the other to large sheaves, the feasibility of the generator engines rendering any assistance to the rope driving engines or vice versa is eliminated.

Comparative Merits of the Corliss Engine and Steam Turbine

There appears to be no local conditions which indi-

cate the suitability of one means of driving these generators more than another. Therefore the only means of arriving at a satisfactory decision is to compare carefully the relative merits of each with regard to reliability, economy, durability, maintenance, and suitability for electric drive. Each point will now be considered carefully and great pains will be taken not to omit any of the minor details of each engine.

The relative points of reliability will be systematically tabulated and compared as follows:

CORLISS ENGINE	STEAM TURBINE
1. Two main sliding stuffing-boxes.	1. Two main rotating stuffing-boxes.
2. Complicated valve gear.	2. Simple valve gear.
3. Vibrations and shock due to reciprocation.	3. Practically no vibration, but uniform rotation.
4. Most frequent accident is rupture of cylinder head which requires a shut-down until new parts can be supplied.	4. Most frequent accident is breaking of blades, but the turbine continues to run without even a momentary shut-down.
5. Many main moving parts.	5. One main driving part.
6. A charge of water may blow out a cylinder head.	6. A charge of water may slow down the turbine momentarily.
7. Possible effect of short circuits or overload is rupture of fly-wheel.	7. Possible effect of short circuits or overload is a momentary shut-down.
8. Continuous overload capacity is 30%.	8. Continuous overload capacity is 75%.
9. Stoppage of cylinder lubrication cuts the cylinder.	9. No cylinder lubrication.

10. Effect on boilers of oil in condensation water is bad and costly.	10. No oil in water of condensation.

These facts show that the turbine is more reliable than the Corliss engine.

Economy of operation includes steam consumption, interest and depreciations, attendance and supplies. For comparisons the attendance is the same for either engine, and as the condensers are also about of equal value, these items will be omitted. As figures have been readily obtained in each case for engines driving 750 Kw. units, these figures will serve for the economy comparison as follows:

CORLISS ENGINE		STEAM TURBINE	
1. First cost of engine and generator	$32,500.00	1. First cost of turbo-generator	$30,000.00
Foundation	3,500.00	Foundation	250.00
	$36,000.00		$30,250.00
2. Cost of operation for one year, using 19 1/2 lbs. water per Kw. hour.		2. Cost of operation for one year, using 20 lbs. water per Kw. hour.	
Coal at .75	$5,133.37	Coal at .75	$5,265.00
Interest at 4%	1,440.00	Interest at 4%	1,210.00
Depreciation 5%	1,800.00	Depreciation 5%	1,512.00
Oil and supplies	1,000.00	Oil and supplies	250.00
Total	$9,373.37	Total	$8,237.50

This shows the turbine to be more economical in every way, and as the efficiency curve of the turbine remains horizontal longer than that of the Corliss engine, the difference in these figures will increase with any change of load.

The maintenance and durability of these engines depend upon the same points as the reliability. The following

points, however, may also be considered:

CORLISS ENGINE	STEAM TURBINE
1. Many sliding and wearing parts.	1. No sliding main wearing parts.
2. No blades subject to erosion.	2. Blades are subject to erosion by wet steam.
3. Parts large and replaced with difficulty.	3. Blades small and easily replaced.
4. Up keep of valve gears expensive.	4. Up keep of valve gears cheap.
5. Oiling points and lubrication require much attention.	5. Few points of lubrication; require little attention.

Again the turbine is found to be superior to the Corliss engine.

The points determining suitability for electric drive are given below:

CORLISS ENGINE	STEAM TURBINE
1. Parallel operation imperfect because of non-uniform rotation.	1. Parallel operation perfect because of uniform rotation.
2. Losses from cross currents and low power factor due to non-uniform rotation.	2. Losses from cross currents eliminated. High power factor.
3. Fair regulation possible, owing to intermittent action of steam.	3. Very good regulation possible, owing to continuous action of steam.

The turbine also seems to be the superior driving power for electric generators.

From the theory of design as well as from experi-

ments the steam turbine shows itself by these comparisons to be superior to the Corliss engine. In addition to the tabulated facts the turbine has the advantage of occupying only 1/4 of the floor area which a Corliss engine of the same horsepower would cover. Besides this, the turbine may merely rest on the engine room floor, allowing all the basement to be used for auxiliary apparatus. The turbine can be started and stopped in about 1/4 of the time required to do the same with the Corliss engine.

Turbo-Generators

Now that the steam turbine is found to be the best for our purpose, and that the number and capacity of the required machines are known, it only remains to decide between the vertical or Curtiss type of turbo-generator and the horizontal unit. For paper-mill machinery no very high buildings are required, and in order to have the engine room uniform with the rest of the mill, there will hardly be enough head room in the engine room to permit of the installation of a Curtiss type of turbo-generator. Although the horizontal unit requires more floor space, there is sufficient room for two of them. If there is any choice or superiority of one make of turbine over another, it is slightly in favor of the Parsons type made by the Westinghouse Company, because it contains less complex working parts, and its builders have had more experience. The

De Laval turbine has not yet been made to run efficiently in such large units as are required here.

Alternating or Direct Current,- Speed Control

Before definitely specifying anything further regarding the turbo-generator, it must be decided whether a direct or alternating current will be most suitable. Of the 575 Kw. required in this plant, about 165 Kw. must drive machinery which will be continually varying in speed.

For the variable speeds the D. C. system at once presents itself as the only satisfactory installation. However, the fact that the machines are generously distributed over the plant requires the use of much transmission wiring, and as the A. C. current can be transmitted at higher voltage and lower amperage and therefore smaller wiring may be used, it is found advisable to consider the efficiencies of various variable speed A. C. motors.

In past electrical practice the idea of furnishing variable speeds from A. C. motors has been considered expensive and unsatisfactory in many ways. In fact there are today only two classes of work for which A. C. motors have proved themselves absolutely suitable in every way. The first of these is work similar to the operation of electric cranes, where in case of a direct current a series wound direct current motor would be used. The second is in cases where the torque remains constant upon the motor, and it is

simply required to adjust the speed of the machine. It has never been found feasible to use A. C. motors on machines requiring variable speed adjustments, when the torque also varies at each adjustment of speed.

In matters of paper-mill technicality it will be very well to consider some opinions of men who have spent their lives in the study of the economical manufacture of paper. Mr. A. R. Bush of the Union Bag and Paper Company advises strongly the use of the constant speed motor, transmitting its power through the Reeves pulley. The Reeves pulley is a conical pulley by which variations in speed of from 1 to 5 may be readily obtained. These have proved to be very satisfactory from every standpoint except economy and convenience. Mr. J. J. Ruckes, a paper-mill designer of New York City, advises the use of an A. C. current and the installation of small converters for the variable speed machinery. This would result in an expensive installation for a small portion of the work and would necessitate the use of the Ward Leonard control. The efficiency would only be about 80%.

There is, however, a system of control of A. C. current speeds which has been experimented with and proved very satisfactory under similar working conditions as are required here, and it has also been highly recommended as absolutely durable and reliable by several of the most conservative electrical engineers throughout the country. At normal

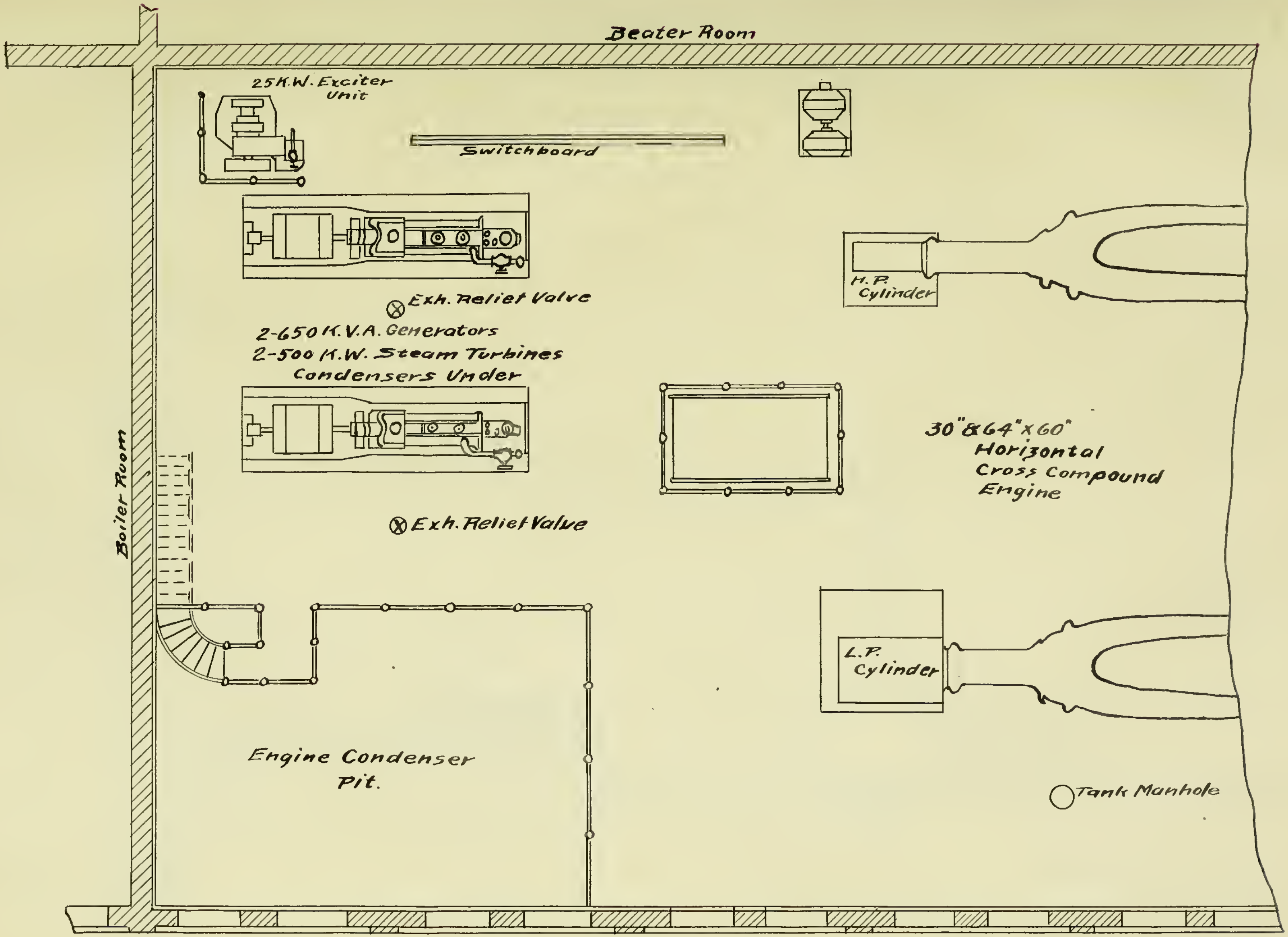
speeds its efficiency is between 85% and 90%, and its installation would not be expensive. The control consists of a water rheostat, to which the motor is connected, and into which surplus electric current is allowed to pass. It is operated by an ordinary controller box. When the limit of this is reached, a small motor driven from the main motor shaft is electrically thrown into the circuit. This motor in turn operates a relay controlling a solenoid which operates the water rheostat. By this means a speed variation of from 1 to 3 is obtained.

The last described system lacks only the recommendations from several years of continuous use, and as otherwise it appears to be by far the most suitable and economical system for our purpose, the A. C. turbo-generators will be installed, operating the variable speed machinery by this method of control.

Having now determined the desired style, capacity, and make of electrical generating units, two 500 Kw., 440-volt, 60-cycle, Westinghouse Parsons, alternating current turbo-generators will be shown in the engine room plans, Plates 2 and 3, located by referring to drawings furnished by the makers. These turbines will operate at about 3600 R. P. M.

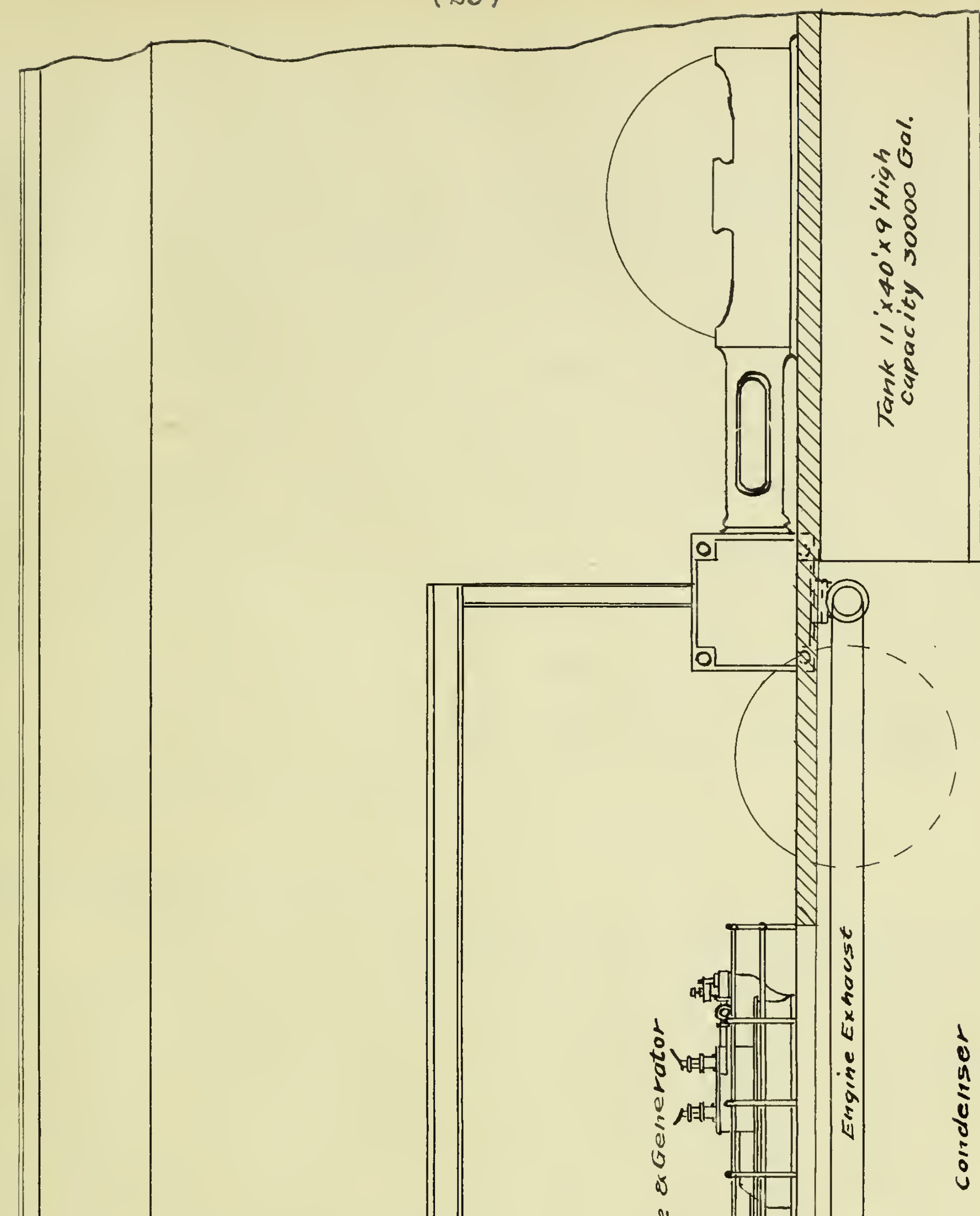
Source of Water Supply

The site of the proposed plant is about 4800 feet



PLAN VIEW
ENGINE ROOM

PLATE 2.



SECTIONAL ELEVATION OF
ENGINE ROOM

PLATE 3.

from the Illinois River, from which an inexhaustible supply of boiler feed and condenser cooling water can be obtained. The piping for such a plant would need to be about 36 inches in diameter. The cost of such piping is very great, and in the marshes and low lands through which this piping must be laid it is almost impossible to obtain laborers who will work there. By inquiries as to the local conditions of the water distribution, it has been found that well-water may be obtained a few feet from the surface. Wells will therefore be sunk, from which the boiler feed water and condenser circulating water can be pumped.

Engine Room Auxiliaries

The Corliss engine has been specified as running condensing, and the turbines must be condensing in order to run economically; therefore three condensers must be installed. These will be placed under the engine room floor as shown on Plates 2 and 3. Piping for circulating water will pass from the wells through each condenser to a sealed tank. A circulating pump driven directly by a 12 H. P. steam engine will help the water to circulate through each of the turbine condensers. The level of the water in the sealed tank can be made low enough so that these pumps will merely have to overcome the friction in the pipes. A similar 20 H. P. engine driven pump will assist the cooling water through the

engine condenser. A tandem connected 10 H. P. exhaust pump will remove air that comes in with the steam. The water of condensation will be piped directly to the feed-water heater. The condensers, which will be surface condensers because of the great sufficiency of circulating water, and their auxiliary pumps and drives, will be furnished by the Wheeler Engineering Company.

In the beater room where the pulp is made, 1,500,000 gallons of water per day are required. For this purpose a 70 H. P. direct connected pump will be furnished by the Wheeler Engineering Company, and will pump its water directly from the sealed tank which receives the circulating waters. The daily amount of circulating water used will always somewhat exceed the amount used by the beater room, and an overflow pipe will be provided at the tank.

At the paper machines water at high pressure is required for showers, wash waters, and on the suction-boxes. To furnish this pressure a 40 H. P. direct connected pressure pump will pump water directly from the wells. This pump will be made by the Gould Manufacturing Company.

Although the plant will be built entirely of brick, concrete and fireproof materials in order to comply with the requirements of the insurance companies, an Underwriters fire pump having a capacity of 1500 gallons per minute

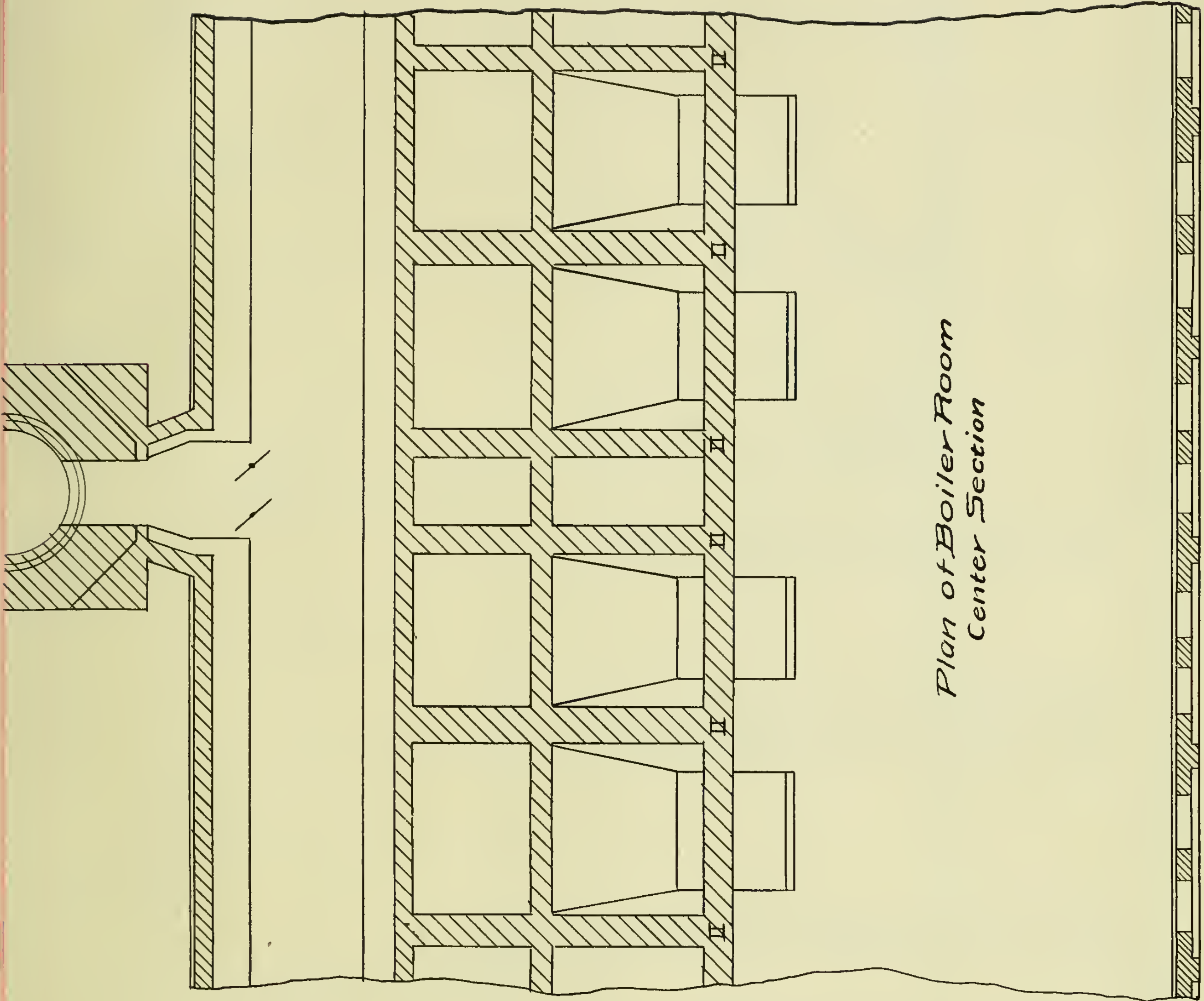
will be installed. No power will be conceded to this pump, however, because in case of fire the entire mill would shut down and power would be plentiful. This will also be a Gould pump.

BOILER ROOM

Handling of Fuel

As previously stated, six 400 H. P. Babcock and Wilcox water-tube boilers will be installed. The most efficient and economical fuel for this plant in its proposed location has been found to be low grade Illinois screenings furnished by the Cuba mines on the Toledo, Peoria & Western Railway and the Hanna mines on the Iowa Central Railway. These coals can be delivered at about 70 cents per ton. The coal will be burned on chain grates made by the Green Engineering Company. They will be fed by distributing pipes leading from bunkers overhead, as shown on Plates 4, 5, and 6. These bunkers will have a total capacity of 500 tons, and will be filled by means of a bucket conveyer having a capacity of 60 tons per hour, made by the Stevens-Adamson Company. This conveyer will extend the full length of the boiler room, both above the bunkers and in the basement, and will rise at the end of the boiler room adjacent to the engine room. An automatic trip furnished by the same people will serve to empty the buckets above the bunkers.

PLATE 4.



Plan of Boiler Room
Center Section

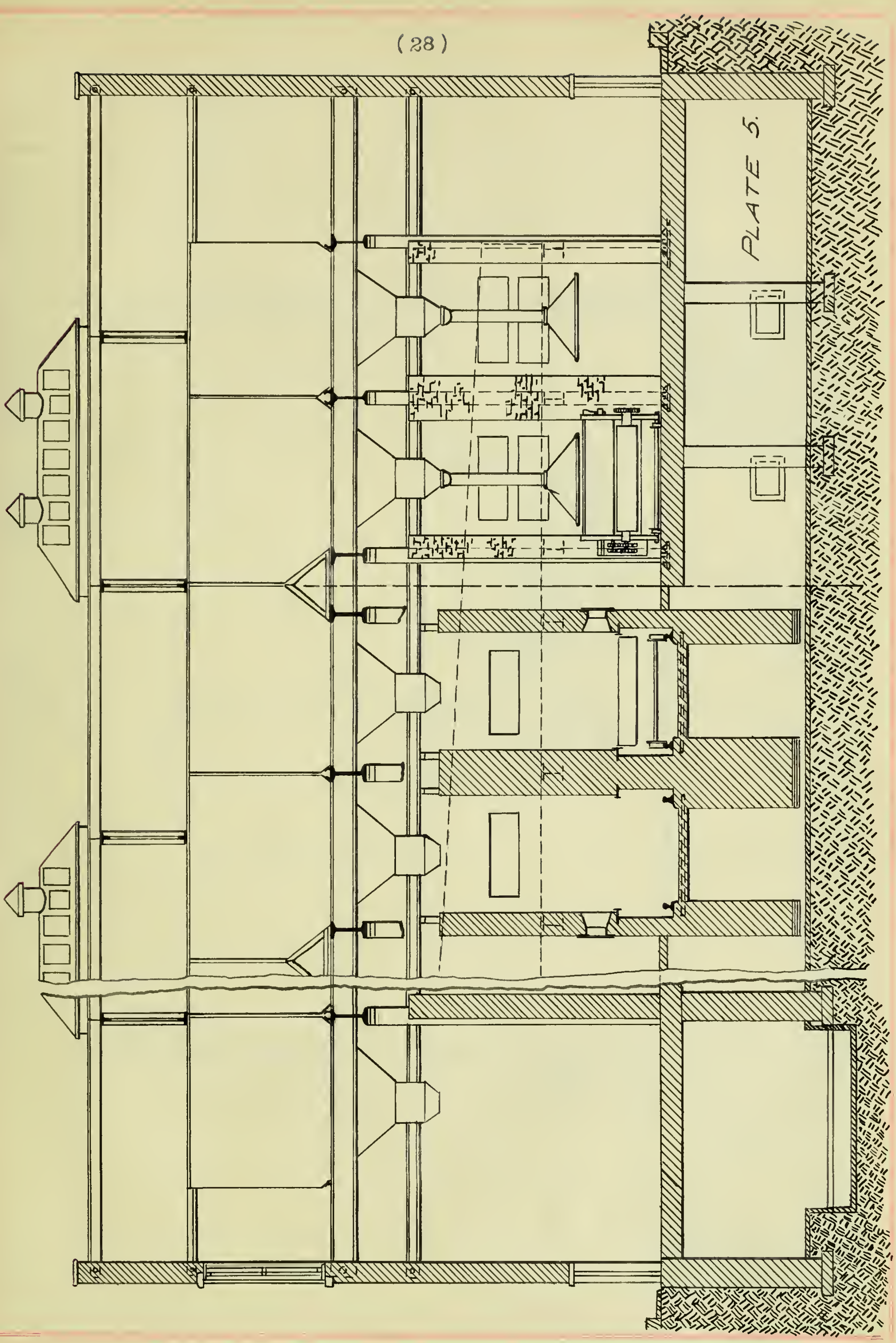


PLATE 5.

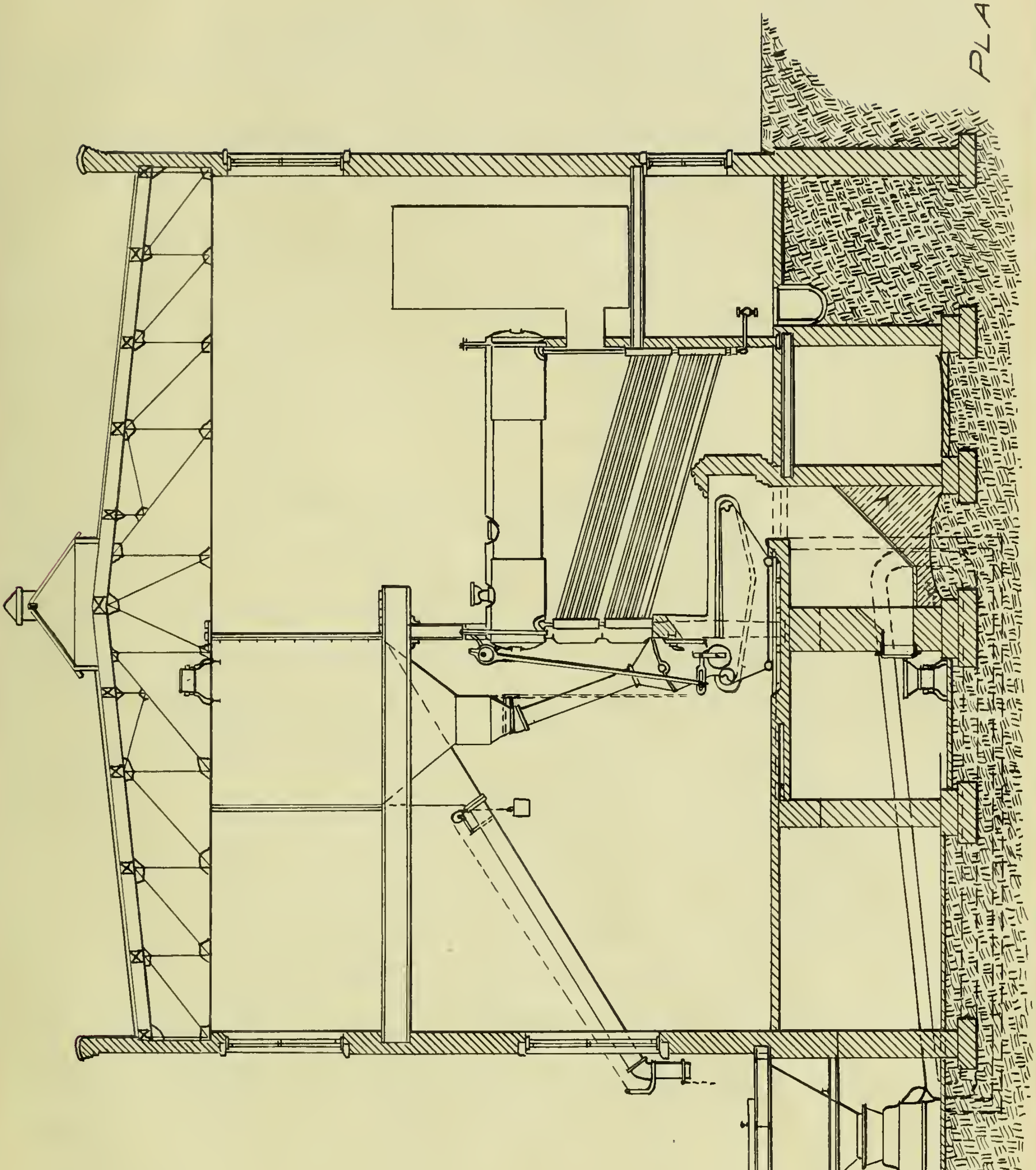


PLATE 6.

The boiler foundations, which will be made of reinforced concrete, will be so constructed as to form ash hoppers of sufficient size under each grate to hold the ashes from at least 10 hours of boiler operation. Outlets to these hoppers will be left in the front wall of the foundation, so that the ashes may be dumped into the coal conveyer and conveyed to an ash bunker overhead. This ash bunker will be so located that its contents can be readily spouted to a car.

The side-track to the boiler house will pass over a coal hole containing a large hopper emptying into a coal crusher and one end of a belt conveyer, which will carry the fuel to the bucket conveyer. The fuel conveyers will be driven by a 25 H. P. General Electric motor located beneath the boiler room floor. For driving the coal crusher a 30 H. P. General Electric motor will be installed in the pit beneath the side-tracks. The main shaft containing the eccentrics for operating the chain grates will be located across the boiler fronts 20 feet above the floor. By means of a belt a 5 H. P. General Electric motor, which will be located beneath the boiler room floor, will drive this shaft.

Feed Water

The Corliss engine and turbine condensing waters

as well as the returns from the heating and auxiliary systems will be piped directly to the feed-water heater. The heater, which will be located in the engine room, will be a 4000 H. P. Cochrane open type of heater. Three 30 H. P. single acting feed-water pumps made by the Fairbanks-Morse Company will be installed. Although two of these pumps are sufficient to furnish the boilers, injectors will also be installed to insure continuous operation of the boiler plant.

An analysis of the water from the proposed wells shows it to contain so much lime and magnesia in the form of carbonates and sulphates that it is found advisable to put in a purifier to treat the make-up water. It is estimated that the make-up water will constitute about 10% of the total boiler water used, and for the purification of this, a 500 H. P. live steam purifier made by the Hoppe Manufacturing Company will be installed in the boiler room. A single 15 H. P. pump made by Fairbanks-Morse Company will force the make-up water through this purifier.

The boilers will not be provided with superheaters for two reasons:

(1) That as most of the steam is used at the large Corliss engine, the high temperature of superheated steam is considered injurious to the joints, stuffing-boxes, and the wearing parts.

(2) That the loop system of steam piping in the

boiler room is contemplated, in which case a great loss of superheat would be realized.

Draft

A metal breeching extending the full length of the battery of boilers in the space between the backs of the boilers and the outside wall will discharge into a smoke-stack located just outside and opposite the center of the boiler room. The breeching will have at its two extreme ends a cross-sectional area of 30 square feet, which will be increased to 60 square feet at the center. The breeching will be covered by asbestos blocks, allowing a 3-inch air-space between the blocks and the metal. These blocks will be plastered on the outside.

A natural draft only will be used on the boilers, and a chimney creating 2 inches of water draft will be designed. A round brick chimney will be built, having an octagonal base and a cast-iron cap. For the required draft it must be 11 1/2 feet inside diameter by 200 feet above the grates.

Piping

In the boiler room the loop system of steam piping will be used. This will enable the drawing of steam from either end of the loop, in case of the necessity of cutting out the steam mains at the opposite end of the battery.

Sufficient loops and allowances for expansions and contractions in the individual mains will be made as shown in Plate 7. Necessary steam separators and valves will be put in as shown.

In the feed-water pipes leading from the heater to the boilers, a similar loop will be used as in the steam header. The make-up water, which is pumped directly from the wells through the purifier, will enter the boiler through independent mains. Two suction pipes from the wells will enter through the wall under the engine room floor. These will be directly connected to the machine supply pump, to the fire pump, and to the condenser circulating pumps, and for cases of some accident at the tank, these will also have direct connections with the mill supply pump and to the feed-water heater. Cut-out valves and by-passes will be put in as shown in piping diagram, Plates 8 and 9.

The exhaust from the turbines and Corliss engine will be discharged directly to the condensers, and each will also be provided with relief valves, for exhausts to the atmosphere. The auxiliary exhausts will be piped to the heater as shown on Plate 10. Grease extractors will be inserted between the engine and feed pumps to preserve the boiler tubes.

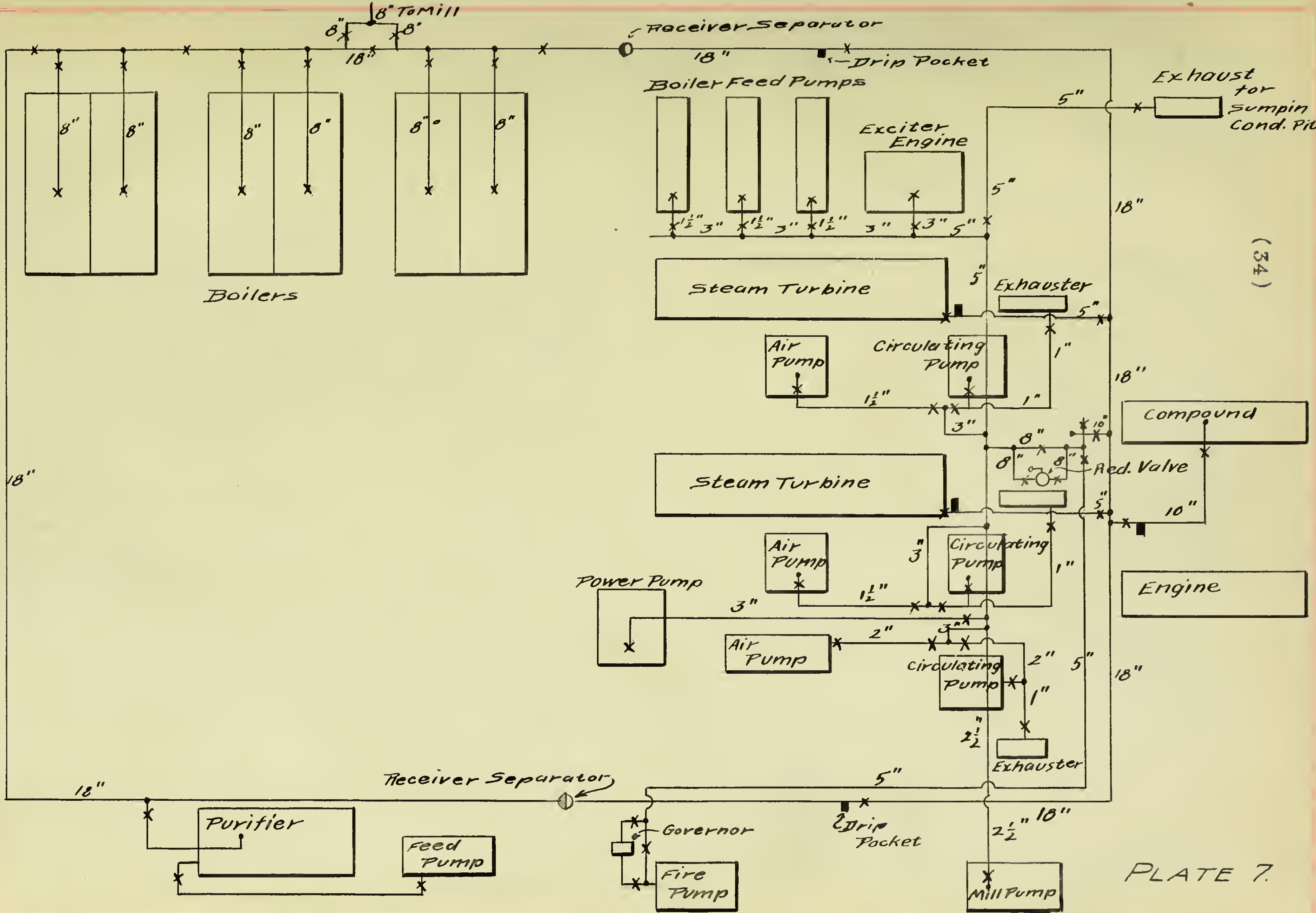


PLATE 7.

STEAM PIPING

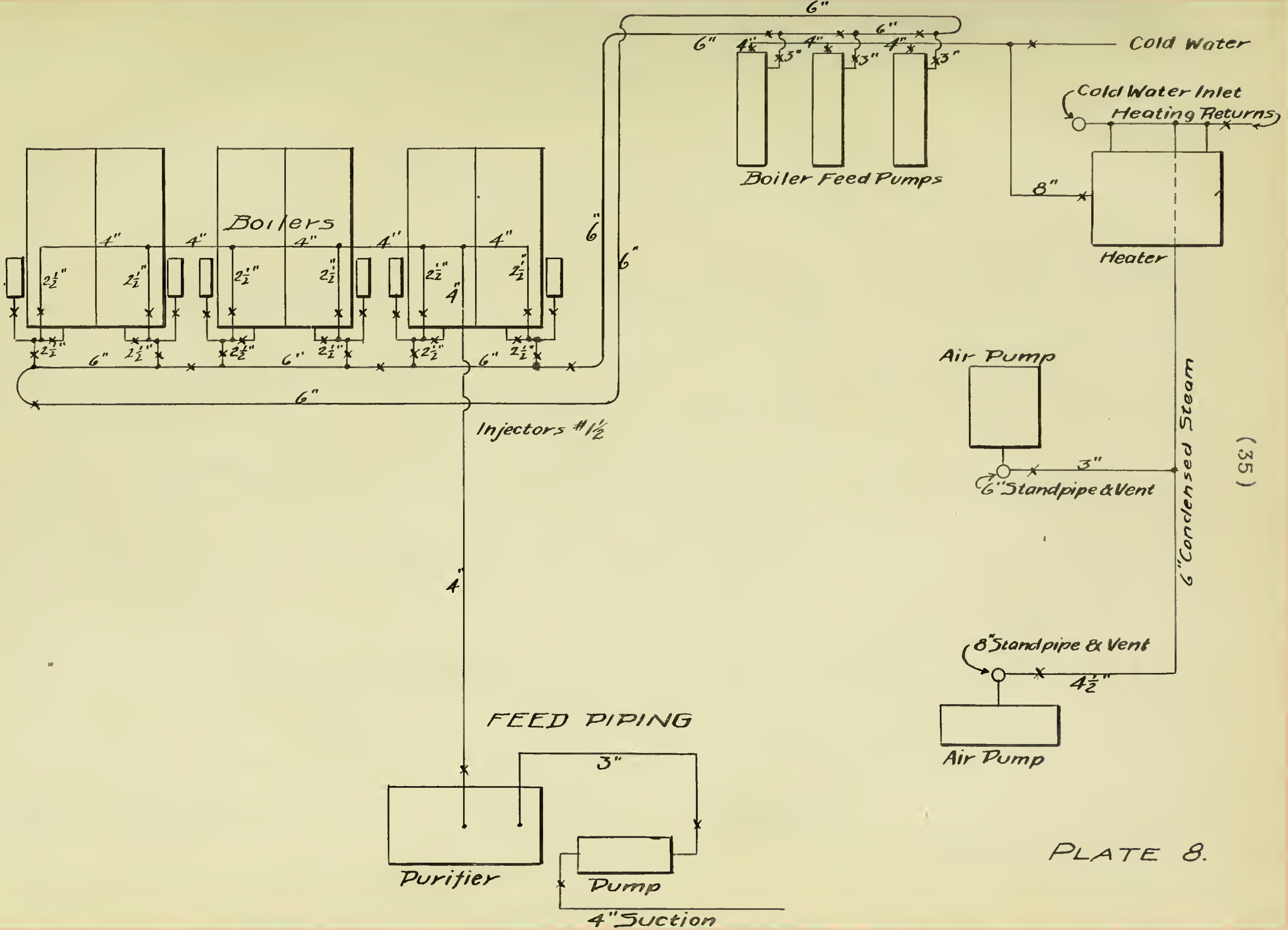

Cold Water
Cold Water Inlet
Heating Returns
Heater
8"
Boiler Feed Pumps
Boilers
Injectors #1½
6" Condensed Steam
Air Pump
3"
6" Standpipe & Vent
8" Standpipe & Vent
4½"
Air Pump
FEED PIPING
Purifier
Pump
3"
4" Suction

PLATE 8.

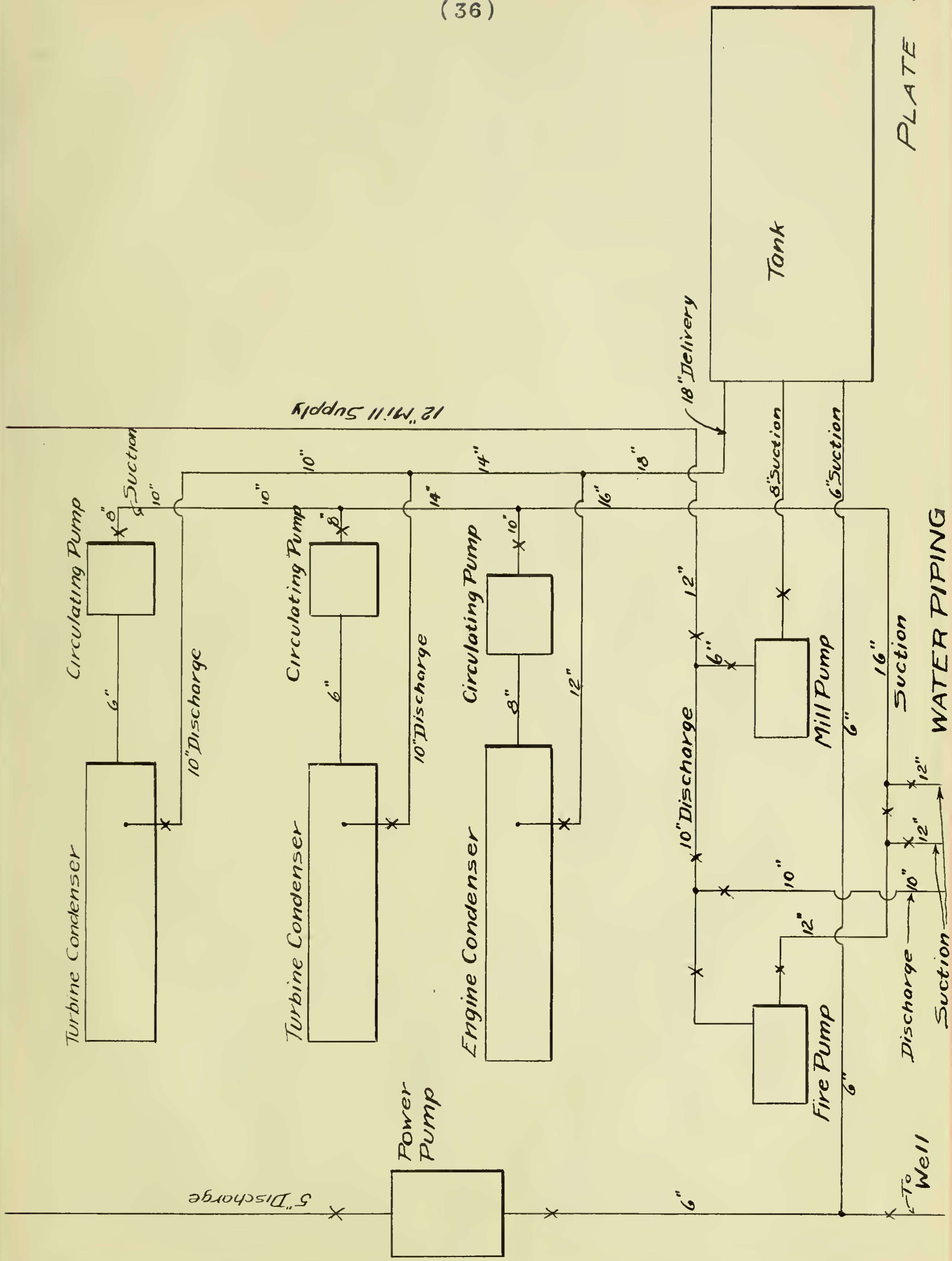


PLATE 9.

WATER PIPING

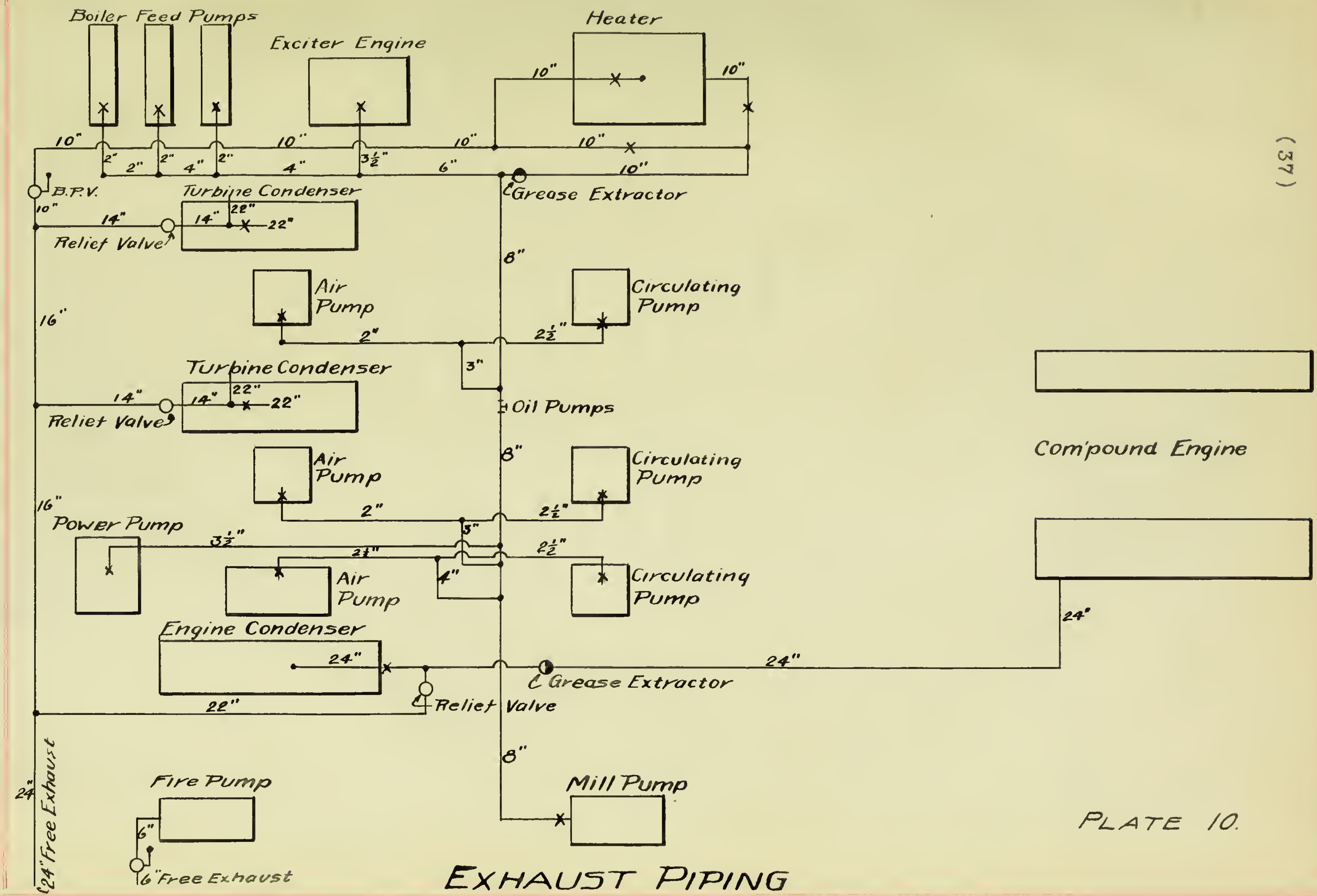


PLATE 10.

EXHAUST PIPING

C O N C L U S I O N

The proposed mill, the analysis of whose power requirements and power plant has now been completed, is larger than any other similar plant in the world. Its machinery is of the most approved type and up-to-date in every respect, and its processes are on the largest efficient scale. With the possible exception of the variable speed arrangement for the electrically driven machinery, every part of the engine and boiler room equipment has been previously used and tested in paper-mill power plants as well as in other branches of manufacture, and has proved to be the most reliable and efficient for its respective purpose.

The completeness and superiority of the design and construction of the buildings of the plant will be in keeping with the machinery and power plant, and the approximate cost of the entire mill when completed will be about one-half million dollars.